Mortaza FARSADI et al. / IU-JEEE Vol. 16(2), (2016), 3007-3015

Loss Reduction Benefit and Voltage Profile Improvement by Considering Demand Response and Capacitor

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Abstract: *The presence of demand response programs (DRPs) in the distribution systems would certainly affect the power system problems such as capacitor studies. Some of these problems refer to economical and other ones are based on technical limits. Capacitor placement and responsive load installation are a challenge that express as the base of distribution system problems which are considered in this paper. In this paper, in order to maximize the loss reduction benefit and voltage profile improvement simultaneously, considering different percentages of peak loads and electricity prices have been studied. Also, a probabilistic load model at each load state is assumed in this paper instead of utilizing time-series based models. Moreover, optimum numbers of capacitors and optimum load reduction by DRP should be used in each load state in order to optimizing the problem. Different scenarios including, individual or simultaneous placing of capacitors and DRPs at each load state have been established and interrogated in depth. Therefore, non-dominated genetic algorithm version II (NSGA-II) has been used to solve the problems under study. NSGA-II is used for a typical network by considering possibilities. The effectiveness of the proposed scheduling approach verified on IEEE 33-bus distribution test system in the planning period. Here the most important part is modeling the probability of load, which can say the load's behavior is following that most of the time in the planning period.*
Keywords: *Loss Reduction Benefit, Voltage Profile Improvement, Demand Response, Capacitor.*

1. Introduction

The active participation of end-side consumers in DRPs could be divided in two folds about incentive-based programs and time-based programs [1]-[2]. In incentive-based programs such as direct load control (DLC), the distribution system controls the consumers demand up to a pre-specified contracted value and prices. These programs are the best tools for distribution systems operators to control the emergency situations such as peak load hours. Time-based programs, by considering the forecasted price of electricity in different hours in the planning period, are mainly activated by the consumers themselves and there is no any direct control on them by the distribution system operator.

Siting the capacitors and other kind of electrical stuffs are used many years as a main part of every electrical systems. Most used methods for this goal are genetic algorithm [3], PSO [4] and other meta-heuristic algorithms [5]. Therefore, different kinds of Intelligent Electronic Devices (IED) that used for many years in power systems, such as smart meters and Distribution Remote Terminal Units (DRTUs) and some other devices developed to profit an online and efficient control on different parts of networks [6, 7]. Different types of consumer such as commercial, industrial, and residential customers can participate in demand request. The strategy is supply in two bases including time-based programs and motivation-based programs [8, 9]. Time based programs, with different electricity prices for different peak loads of day ahead hours in the planning period, are generally used for encourage customers to use in the best way, but behind all this policies it is important to use some IED to have stability and more certainty.

In this paper the using shunt capacitors and DRPs is aimed to reach a various kind of proposes consist on loss reduction benefit and voltage profile improvement. Shunt capacitors are popular to solve some problems in distribution network [10, 11]. Except reduction in power losses, the shunt capacitors improve the voltage profile, power factor, voltage stability of the system and so on [12]. Using capacitors and DRPs in distribution systems in most of the papers and plans are a way to reach some golden aims. Some kinds of energy sources such as Distribution Generation (DG) and Energy Storage System (ESS) have been used with capacitors in distribution networks in order to optimize different objectives. For example in paper [13], the authors used a multi-objective method for locating DGs like wind power generation in the distribution network. In paper [14] the Differential Evolutionary (DE) algorithm has been used. In paper [15],

Received on: 22.02.2016
Accepted on: 10.05.2016

the method that used is wavelet transform and hybrid principal component network analysis. The author in [16] proposed an optimal strategy for simultaneous allocation of DGs and capacitors in active distribution networks making use of online reconfigurations. They have also presented interesting results in this paper. The authors in [17] proposed the new strategy for maximizing the loss reduction benefit and improving the voltage profile by considering different electricity prices and specific probability for each load state. They have also used the online switching for capacitors operation. However, the existence of capacitors by considering the DRPs have been neglected in the abovementioned works.

Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and Dynamic Programming (DP) are popular methods in most of the papers. GA that is a sort of probabilistic heuristic algorithms produces a way for optimization problems by using methods motivated by natural evolution in nature such as legacy, mutation, mixture, and crossover [18]. PSO is one of other methods for optimization that is a computational algorithm to optimize by iteratively trying to progress a contestant solution. PSO optimizes by having a population of first fortuitous solutions [18]. DP as another way is a method for solving a difficult problem by breaking it down into an assembly of simpler sub-problems [19].

The most important thing which must consider is that each of the prior methods has some problems, for example GA and PSO aren't adequate for solving the multi-objective problems and the DP might finally effect on the sizes of the problem, thus requiring giant calculations.

The method that is used in this paper is Non-dominated Sorting Genetic Algorithm version II (NSGA-II) [20]. The most important thing about NSGA-II is that can sort last answers in a way that the best answers can compete between each other in every moment and it can reach multi goals together. NSGA-II have been used in this paper in order to maximize the loss reduction benefit and improve the voltage profile by considering different load states, electricity prices for each state, and also considering the probability of each state during the planning period. After this step it's important to get the optimum number of capacitors, and optimum percentage of load reduction by responsive loads that are online in each load state and in duration of planning period. The effectiveness of the proposed method verified on a 33-bus distribution test system over the planning period.

This paper is organized in 6 sections. The NSGA-II algorithm is presented in section 2. Section 3 is prepared to describe the methodology. Evaluate the Objective Functions and simulation results are provided in section 4 and 5 respectively. Eventually, conclusion is presented in section 6.

2. NSGA-II Algorithm

NSGA-II that is used in this paper as the main algorithm, is a relative of GA .GA as an intelligent algorithm reproduces the natural selection manner. In this method, the most qualified parents would be luckier to replace their genetic code to the future offspring. This procedure known as evolution process employed by specific probability operators namely crossover, mutation, selection etc. By this method, GA would be appropriate to carefully inquiry the search space and then find the optimal answers [21, 22].

NSGA is an algorithm from the family of the GA for multiple objective function optimizations. It is related to other evolutionary Multiple Objective Optimization (MOO) methods such as Strength Pareto Evolutionary Algorithm (SPEA), and Pareto Archived Evolution Strategy (PAES). The updated and currently canonical form NSGA is its version II [23].

The first aim is to minimize the function as it's mentioned in equation (1):

$$\begin{aligned} &\min F(x) = \{f_i(x),...,f_n(x)\} \\ &s.t:\ g(x) \le 0,\ \ h(x) = 0 \\ &x \subset \Re \end{aligned} \tag{1}$$

In this equation, F(x) is main function that consist i parts. fi(x) is the i-th function that is going to optimize by multi-objective algorithm. g(x) and h(x) are limits that g(x) is related to non-equal limits and h(x) is equality limits. The "Fig. 1" shows a multi-objective algorithm with two typical functions.

In "Fig. 1", it's obvious that A and B are better than C as an answer to optimization and minimization. But, which between A and B are better than other one is not clear. So, it's defined a subject with the name of "dominate". When it is said X1 dominate X2, it means X2 in no aspect is better than X1. After non-dominating sort of answers, the second part is defining "Pareto Front". The "Fig. 2", shows the "Pareto Front" for a typical function consists two sub-functions.

As it's showen, the border around the answers is "Pareto Front" which appears and as a simple explanation, it's the feasible answers which can happen and use by considering limits and other conditions. The next step is defining and sorting answers to groups (for example in 3 groups). This part will cut our answers to 3 parts, F1, F2, and F3.

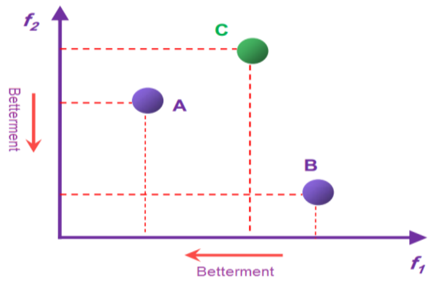

Fig. 1. A multi-objective algorithm with two function.

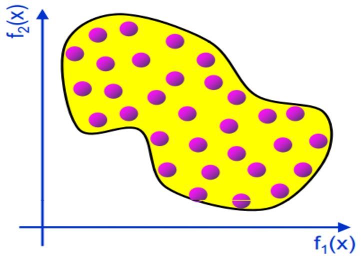

Fig. 2. Pareto Front for a typical problem.

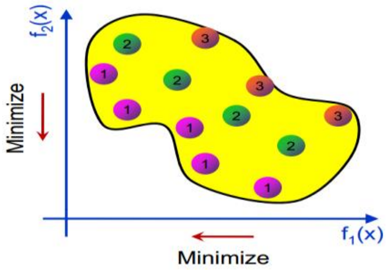

Fig. 3. Grouping answers.

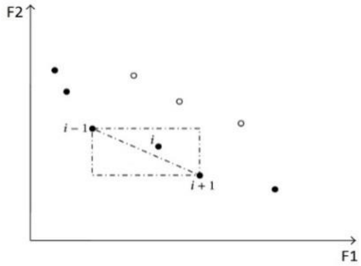

Fig. 4. Crowding distance calculation.

The next step in "Fig. 3" algorithm will omit the answers which excess than population size. Then it's important to calculating crowding distance that showed in "Fig. 4".

In equation (2) the "Crowding Distance" can be seen which separate the best answer. The "Crowding distance" is a concept that omits the answers near to each other and keep the answer that are various in one or more aspect to have a vast gamut of answers. The incensement of dj(k) shows the improvement of answer because of distance between them. For example as it's shown in "Fig. 4", the particle (answer) i-th's relativity between i-1 and i+1 is shown in equation (2). The end step in algorithm applies crossover and mutation on answers that give the best answers as it's in GA.

$$d_j(k) = \sum_{i=1}^{n} \frac{f_i(k-1) - f_i(k+1)}{f_i^{\max} - f_i^{\min}} \tag{2}$$

3. Methodology

In this section, the general methodology employed in this paper is presented. The loading at each bus is assumed to follow the load shape. The load data has been clustered into 10 distinct load states. The loading levels, electricity prices, and the probabilistic models of load during the planning period for each state are given in "Fig. 5". As shown in this figure, electricity prices are different for each load state. For example, at maximum peak load state the electricity price is 0.031 \$/kWh and the probability of this state is 1% (0.01).

The outputs of this methodology are the optimal location of the capacitors and responsive loads in the distribution network

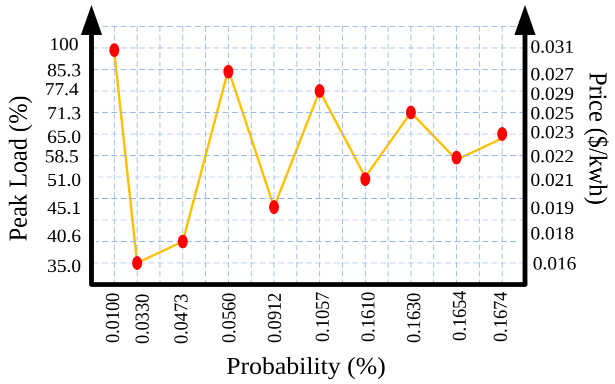

Fig. 5. Structure of the proposed methodology

and also the optimum numbers of capacitors and percentage of load reduction by responsive loads in each load state would been determined in order to optimize the objective functions under study.

The proposed methodology is based on the following assumptions:

- The network is balanced during the planning period.
- There is limited budget for placing of capacitors and totally, two kinds of capacitors have been selected, 300 Kvar capacitors and 600 Kvar capacitors.
- The capacitors have been controlled online for switching the optimum number of capacitors in each load state.
- There are five capacitors in this study. Three capacitors are 300 Kvar and two capacitors are 600 Kvar.
- There is limited budget for using DRPs; hence, the program which has been used is direct load control program.
- Number of loads that participate in the DRPs are three loads with adaptive load reduction percent at each load state.

Duration of planning period is one year with specific probability for each load state.

4. Evaluation of Objective Functions

Capacitors would be considered to install at different buses for injecting reactive power to the network, and

DRPs would considered at three different buses in order to optimize the percentage of load reduction. Capacitors and DRPs due to their excellent capabilities, could utilize to attain several objectives such as power losses minimization and voltage profile improvement. Herein, the most important purpose is to maximize the loss reduction benefits and improvement of voltage profile in the network represented as follows in equation (3) and equation (4):

$OF1$

$$LRB = 8760 \times \sum_{Ls} \rho_{LS} \times C_{LS} \times (P_{Loss}^{WithoutC\,\&DRP} - P_{Loss}^{WithC\,\&DRP}) \quad (3)$$

$OF2$

$$VPI = \sum_{LS} (\Delta V_{WithoutC\,\&DRP}^{LS} - \Delta V_{WithC\,\&DRP}^{LS}) \quad (4)$$

Where, LRB represents the loss reduction benefit, Ls is the load states index, ρ_{Ls} and CLS are the probability and electricity price for each load state respectively, and $P_{Loss}^{WithoutC\,\&DRP}$ and $P_{Loss}^{WithC\,\&DRP}$ represents the total power losses for each state without and with capacitor and DRP, respectively. VPI, is the second objective function that represents the voltage profile improvement in the network under study. $\Delta V_{WithoutC\,\&DRP}^{LS}$ and $\Delta V_{WithC\,\&DRP}^{LS}$ represents the sum of total buses voltage profile without and with capacitor and DRP at load states (LS), respectively.

The sum of total buses voltage profile is represented by equation (5):

$$\Delta V^{LS} = \sum_{i=1}^{Nbus} (V_s - V_i)^2 \quad (5)$$

Where, Vs is the voltage of substation that is assumed equal to 1 (Vs =1), and V_i is the voltage of *i-th* bus. Note that ΔV^{LS} is the total buses voltage profile for load state *LS*. DLC as one of the most effective DRPs in peak load states management is considered to be contacted between the distribution network operators and some large customers in the distribution system. Therefore, the problem constraints such as load flow balances, and voltage limits, for each combined load-capacitor-DLC state (Ls), are presented as follows in equation (6) and (7):

$$P_{g_{i,Ls}} + P_{DLC_{i,Ls}} - P_{L_{i,Ls}} = \sum_{j \in \Omega_i} P_{ij}(V_{i,Ls}, V_{j,Ls}, Y_{ij}, \theta_{ij}) \quad (6)$$

$$Q_{g_{i,Ls}} + Q_{DLC_{i,Ls}} + Q_{C_{i,Ls}} - Q_{L_{i,Ls}} = \sum_{j \in \Omega_i} Q_{ij}(V_{i,Ls}, V_{j,Ls}, Y_{ij}, \theta_{ij}) \quad (7)$$

Where, $Q_{C_{i,Ls}}$ is reactive power generation by capacitor at bus *i* and state *Ls* respectively. $P_{DLC_{i,Ls}}$ and $Q_{DLC_{i,Ls}}$ represents active and reactive power reduction by DLC responsive load at load state *Ls* and bus *i*, respectively. $P_{L_{i,Ls}}$ and $Q_{L_{i,Ls}}$ represents active and reactive power of distribution network feeder at each load state respectively, $V_{i,Ls}$ and $V_{j,Ls}$ are bus voltages at bus *i* and bus j at each load state respectively, finally Y_{ij} and θ_{ij} are the magnitude and phase angle of feeder's admittance, respectively.

$P_{g_{i,Ls}}, Q_{g_{i,Ls}}$ are active and reactive power generate in each bus and P_{ij}, Q_{ij} respectively are active and reactive powers which transmits between bus *i* and *j*.

Proper constraints are required to assurance the voltage magnitude to be kept at permissible range at each bus.

$$V_{\min} \le |V_{i,Ls}| \le V_{\max} \quad (8)$$

Where, *Vmin* and *Vmax* are minimum and maximum limits of bus voltages for each load state respectively and i is indices of buses.

As the initial investment capital of distribution network operator may be limited, there will be a maximum cap for considering the DRPs for DLC in the distribution network and implementing DLC demand response between some large consumers. Determination of installation buses for DLC, itself will have a great effect on the optimal solutions for capacitors sites and number at each load state. Hence, it should be modeled as a part of optimization procedure. The maximum number of considered DLC loads would be taken as $N_{DLC}^{\max}$. Also, each candidate bus that is selected as a DLC responsive load, should satisfy the optimum amount of permissible load reduction indicated by PER_{DLC} (%), that is, the percent of MVA reduction in each bus. The following constraints are taken to be observed:

$$N_{DLC} = N_{DLC}^{\max} \quad (9)$$

$$\left[\left(P_{DLC_i}\right)^2 + \left(Q_{DLC_i}\right)^2 \right]^{1/2} \le \frac{PER_{DLC}(\%)}{100} \times S_{L_i}, \quad i \in \Omega_B \quad (10)$$

$$PF_{L_i} = \frac{P_{L_i}}{\left(P_{L_i} + Q_{L_i}\right)^{1/2}} = \text{cte}, \quad i \in \Omega_B \quad (11)$$

$$Q_{DLC_i} = \tan(\cos^{-1}(PF_{L_i}) \times P_{DLC_i}, \quad i \in \Omega_B \quad (12)$$

Where, PF_{L_i} is constant power factor of load in each bus subjected to be equipped with DLC.

Multi-Scenario have been determined for optimal sizing and siting of capacitors and responsive loads in to distribution system under study. To present a comprehensive investigation, four different scenarios have been devised as the following:

- Scenario1: Distribution system without considering capacitors and DRPs (base plan);
- Scenario2: Distribution system with considering only capacitors;
- Scenario3: Distribution system with considering only DRPS;
- Scenario4: Distribution system with considering capacitors and DRPs, simultaneously;

Base plan represents the basic structure of the test system without any capacitors and DRPs. In the following, simulation results are obtained for each scenario and discussed in depth.

5. Simulation results and discussion

As shown in Fig. 6, IEEE 33-bus radial distribution system has been used as case study. The rated active and reactive power ranks of the load points as well as the feeder data are taken from [24]. The system's active and reactive powers in peak load state are 3.715 MW and 2.3 MVA, respectively. For this case study, bus 1 is connected to the sub transmission network and is assumed as the substation.

NSGA-II has been applied with various crossovers and mutations in each iteration. The best results are obtained with population size of 100, recombination rate equal with 0.5 and mutation factor accustomed at 0.01, respectively. Note that NSGA-II and its parent GA, as one of the heuristic algorithms, does not guarantee the same answer even after running the same problem numerous times but they are all acceptable. Consequently, in this study NSGA-II's run was repeated 15 times and saved optimal solution results. This section summarizes optimum results of this study, optimal siting of capacitor units and responsive loads in order to achieve maximum loss reduction benefit and voltage profile improvement. The impact of allocated capacitors and DRP have been studied in this section through comparing four different scenarios, and also selecting the optimum numbers of capacitors and optimum percentage of load reduction by responsive loads have been discussed in this section.

"Table. 1 provides the obtained numerical results for test system in different scenarios where the optimal power loss and voltage profile have been determined by considering different load state and specific electricity price for each load state. As shown in this table, power loss and voltage profile considering the probability of each state and their electricity prices, have determined during a year for each scenario. As shown, scenario 4 has optimum results for loss and voltage profile. Table. 2, shows the optimum number of capacitors and percentage of responsive load at each load state for each scenario. It is worthy to note that, using DRP for peak load shaving have been considered in four states which have higher peak than others. Therefore, states 7 to 10 with 71.3 %, 77.4 %, 85.3 %, and 100% of peak load have been selected for using DRP. As shown in this table, the number of capacitors are increased at high load states.

Table. 3 shows the optimal place for capacitors and responsive load. As shown in this table, bus 13 and 30 are optimal buse for 300kvar, and 600 kvar capacitors, respectively. As mentioned, there aren't any responsive loads in scenario 2. Bus 8, 13, and 28 are optimal buses for using DRP in scenario 3 and reduce the costumers load with adaptive percentage of load reduction. In Scenario 4, optimal place for capacitors and DRP are bus 12, and bus 30 for 300 kvar, and 600 kvar capacitors, respectively and bus 14, bus 18, and bus 30 for DRP. Eventually, table. 4 represents the optimal results for objective functions. As shown here, in scenario 2 optimum result for frst and second objective functions are 4874$, and 1.1177. In scenario 3, loss reduction benefit is 228 $, and voltage profile improvement is 0.0258. As shown here, scenario 2 is better than scenario 3 by considering each objective function. Scenario 4 shows that optimum placement of capacitors and responsive load simultaneously have more effect on loss reduction benefit and voltage profile improvement. In this scenario 5133 $ is optimum benefit for loss reduction and 1.18567 is the optimum voltage profile among these scenarios.

The acceptable range for voltage magnitudes in all buses and each load state has been determined to be between 0.95 p.u and 1.05 p.u respectively.

Fig. 7 and Fig. 8 depicts the voltage profile for the test system without and with considering capacitor and DRP, respectively and the voltage profile for test system has been compared between scenario 1, and 4. As it is seen, voltage profiles of the test system without capacitors and DRP are not in acceptable ranges but with capacitors and DRP in scenario 4 are limited in the allowable ranges.

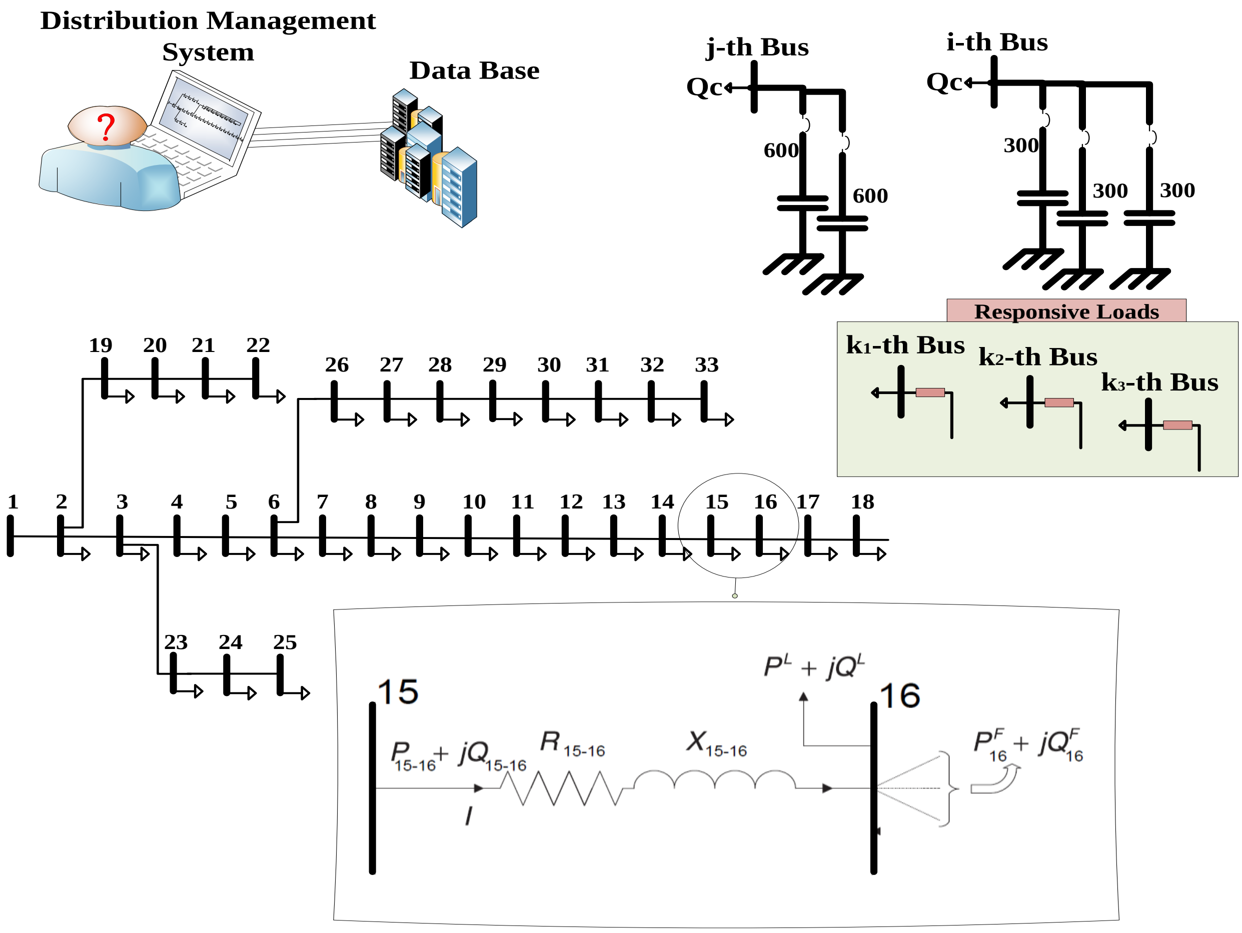

Fig. 6. The schematic diagram of the IEEE's 33-bus radial distribution system.

Table 1. Optimal results for test system.

Load State No.		1	2	3	4	5	6	7	8	9	10
Peak Load (%)		35.0	40.6	45.1	51.0	58.5	65.0	71.3	77.4	85.3	100
Probability (ρ_{LS}) (%)		3.30	4.73	9.12	16.10	16.54	16.74	16.30	10.57	5.60	1.00
Price (C_{LS}) (\$/kWh)		0.016	0.018	0.019	0.021	0.022	0.023	0.025	0.027	0.029	0.031
Scenario 1	$P_{Loss}^{WithoutC\,\&DR}$ (kW)	23.40	31.71	39.41	50.83	67.63	84.31	104.3	121.8	149.9	210.9
	$\Delta V_{Without\ C\,\&DR}$	0.015	0.032	0.059	0.092	0.134	0.187	0.253	0.330	0.425	0.559
Scenario 2	P_{Loss}^{WithC} (kW)	18.1	23.64	34.25	35.80	46.69	58.07	72.19	85.78	108.0	157.7
	$\Delta V_{With\ C}$	0.008	0.023	0.035	0.047	0.067	0.093	0.128	0.159	0.188	0.226
Scenario 3	P_{Loss}^{WithDR} (kW)	23.40	31.71	39.41	50.83	67.63	84.31	100.5	119.6	144.1	202.0
	$\Delta V_{With\ DR}$	0.015	0.032	0.059	0.092	0.134	0.187	0.25	0.326	0.416	0.544
Scenario 4	$P_{Loss}^{WithC\,\&DR}$ (kW)	18.1	23.51	28.5	35.53	46.51	57.98	71.39	85.35	106.8	142.3
	$\Delta V_{With\ C\,\&DR}$	0.007	0.019	0.03	0.041	0.061	0.089	0.114	0.146	0.176	0.215

In Fig. 9, the "Pareto Front" as it's described, illustrated for load state 10. This load state is the maximum peak load which it is the most important load state for showing NSGA-II effect on decreasing the power losses cost and improving the voltage profile. It is mention again that first function should be maximized by an increment in difference between power loss cost by considering capacitors and DRP, and without considering them. The last and best answers for both functions are highlighted by a circle in this figure.

Table 2. Optimum number of capacitors and percentage of responsive load at each load state.

	Load State No.	1	2	3	4	5	6	7	8	9	10
Scenario 2	Optimum number of 300 Kvar capacitor	0	0	1	1	1	1	1	2	2	3
	Optimum number of 600 Kvar capacitor	1	1	0	1	1	1	1	1	2	2
Scenario 3	Optimum percentage of responsive load 1	-	-	-	-	-	-	6 %	8 %	14 %	17 %
	Optimum percentage of responsive load 2	-	-	-	-	-	-	9 %	9 %	18 %	17 %
	Optimum percentage of responsive load 3	-	-	-	-	-	-	10 %	5 %	19 %	20 %
Scenario 4	Optimum number of 300 Kvar capacitor	0	0	1	1	1	1	2	2	3	3
	Optimum number of 600 Kvar capacitor	1	1	1	1	1	1	1	1	1	2
	Optimum percentage of responsive load 1	-	-	-	-	-	-	9 %	10 %	16 %	18 %
	Optimum percentage of responsive load 2	-	-	-	-	-	-	7 %	9 %	19 %	20 %
	Optimum percentage of responsive load 3	-	-	-	-	-	-	4 %	8 %	17 %	20 %

Table 3. Optimal place for capacitors and responsive load.

Scenarios		Scenario 2		Scenario 3		Scenario 4	
Optimal capacitors site		Bus 13 300 kvar	Bus 30 600kvar	-	-	Bus 12 300 kvar	Bus 30 600 kvar
Optimal responsive loads site	responsive load 1	-		Bus 8		Bus 14	
	responsive load 2	-		Bus 13		Bus 18	
	responsive load 3	-		Bus 28		Bus 30	

Table 4. Optimal results for objective functions.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
$OF1 \quad LRB = 8760 \times \sum_{Ls} \rho_{LS} \times C_{LS} \times (P_{Loss}^{Without} - P_{Loss}^{With})$	-------	4874 $	228 $	5133 $
$OF2 \quad VPI = \sum_{LS} (\Delta V_{Without}^{LS} - \Delta V_{With}^{LS})$	-------	1.1177	0.0258	1.18567

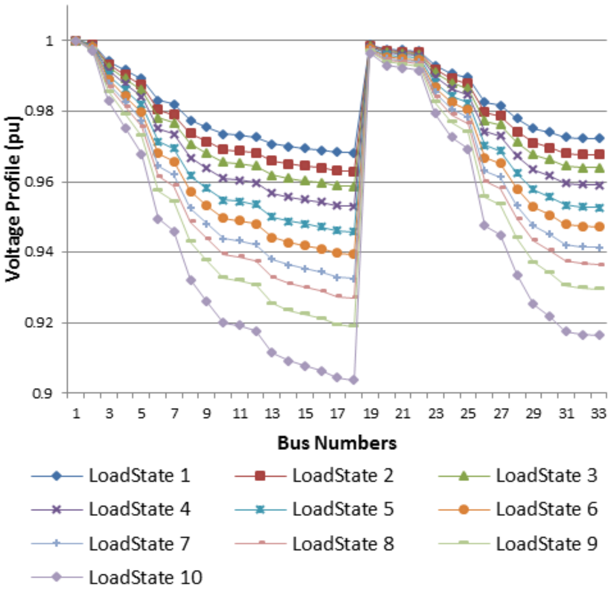

Fig. 7. Voltage profile without capacitor and DRP.

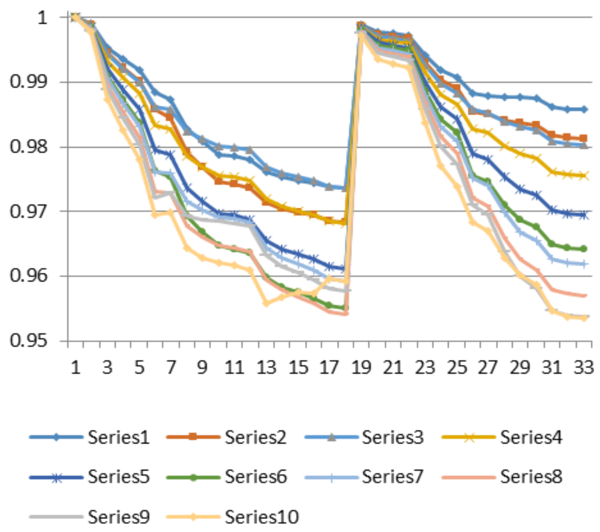

Fig. 8. Voltage profile with capacitor and DRP.

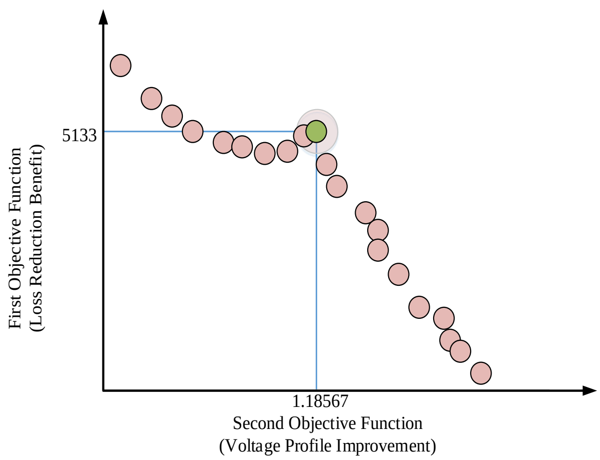

Fig. 9. Pareto Front for load state 10.

6. Conclusion

In this paper, by presenting a comprehensive mathematical formulation, simultaneously allocation of two types of capacitors and DRP have been modeled based on NSGA-II. Capacitor and DRP allocation is one of the important problems in the future distribution networks such as active distribution networks and smart grids which is presented in this paper.

This study proposed the method by considering the probability of load states with their special electricity prices in the planning period in order to maximizing the voltage profile improvement and loss reduction benefits, simultaneously. It was shown that applying capacitor units and DRP which results in higher both reactive power, and active power support, would have a considerable effect on voltage profile and energy losses cost. By this way, the optimal numbers of capacitors and optimum percentage of loss reduction at each state have been assigned as well. NSGA-II method has been used to solve the problems under study. The value of the proposed scheduling method has been confirmed on IEEE 33-bus test distribution test system. Subsequently, it is required for distribution network operators to consider the numbers of capacitors in the expansion planning problems as well as siting and sizing issues in the future active and smart distribution systems.

7. References

[1] P. Siano, “Demand response and smart grids—A survey,” *Renewable and Sustainable Energy Reviews*, vol.30, pp.461-478, 2014.

[2] B. Chakrabarti, D. Bullen, C. Edwards, C. Callaghan, “Demand Response in the New Zealand Electricity Market,” *in Proc. Transmission and Distribution Conference and Exposition, IEEE PES*, pp.1-7, 2012.

[3] Sundhararajan, Srinivasan, and Anil Pahwa. "Optimal selection of capacitors for radial distribution systems using a genetic algorithm." *IEEE Transactions on Power Systems*, 9.3 (1994): 1499-1507.

[4] Eajal, Abdelsalam, and M. E. El-Hawary. "Optimal capacitor placement and sizing in unbalanced distribution systems with harmonics consideration using particle swarm optimization." *IEEE Transactions on Power Delivery*, 25. 3 (2010): 1734-1741.

[5] Sirjani, Reza, M. Azah, and Hussain Shareef. "Heuristic optimization techniques to determine optimal capacitor placement and sizing in radial distribution networks: a comprehensive review." *Przegląd Elektrotechniczny (Electr. Rev.)* 88.7a (2012): 1-7.

[6] Hu, Z. and Li, F., "Cost-benefit analyses of active distribution network management, part i: Annual benefit analysis", *IEEE Transactions on Smart Grid*, Vol. 3, No. 3, (2012), 1067-1074.

[7] M. Dougall, P., Heskes, P., Crolla, P., Burt, G. and C. Warmer, "Fast demand response in support of the active distribution network", *22nd International Conference and Exhibition on Electricity Distribution, CIRED.*

[8] Chakrabarti, B., Bullen, D., Edwards, C. and Callaghan, C., "Demand response in the new zealand electricity market", *Transmission and Distribution Conference and Exposition (T&D), IEEE PES*, (2012), 1-7.

[9] Palensky, P. and Dietrich, D., "Demand side management: Demand response, intelligent energy systems, and smart loads", *IEEE Transactions on Industrial Informatics*, Vol. 7, No. 3, (2011), 381-388.
[10] Gallego RA, Monticelli AJ, Romero R. "Optimal capacitor placement in radial distribution networks". *IEEE Trans Power Syst* 2001; 16 (4):630–7.
[11] Ng HN, Salama MMA, Chikhani AY. "Classification of capacitor allocation techniques", *IEEE Trans Power Deliv* 2000;15:387–92.
[12] Chians HD, Wang JC, Cockings O, Shin HD " Optimal capacitor placement in distribution systems: Part I, Part II ". *IEEE Trans Power Deliv* 1990;5(2):643–7.
[13] Zakariazadeh, Alireza, Shahram Jadid, and Pierluigi Siano. "Economic-environmental energy and reserve scheduling of smart distribution systems: A multiobjective mathematical programming approach." *Energy Conversion and Management* 78 (2014): 151-164.
[14] Dideban, Mohammadhosein, et al. "Optimal Location and Sizing of Shunt Capacitors in Distribution Systems by Considering Different Load Scenarios." *Journal of Electrical Engineering & Technology* 8.5 (2013): 1012-1020.
[15] Hong, Ying-Yi, and Bo-Yuan Chen. "Locating switched capacitor using wavelet transform and hybrid principal component analysis network." *IEEE Transactions on Power Delivery,* 22.2 (2007): 1145-1152.
[16] S. Golshannavaz, "Optimal Simultaneous Siting and Sizing of DGs and Capacitors Considering Reconfiguration in Smart Automated Distribution Systems," J Intelligent Fuzzy Syst, 27 (4), pp. 1719-1729, 2014.
[17] M. Farsadi1, T. Sattarpour Dizaji, and H. Hosseinnejad "Capacitor Allocation in Order to Maximize the Loss Reduction Benefit and Improve the Voltage Profile Based on NSGA-II", *9th International conference on ELECO, IEEE index*. 2015, 1-6.
[18] Lian, Zi-Xiong, and J. Duncan Glover. "A zoom feature for a dynamic programming solution to economic dispatch including transmission losses." *IEEE Transactions on Power Systems,* 7.2 (1992): 544-550.
[19] Fogel, David B. Evolutionary computation: toward a new philosophy of machine intelligence. Vol. 1. John *Wiley & Sons,* 2006.
[20] Eberhart, Russell C., and Yuhui Shi. "Comparison between genetic algorithms and particle swarm optimization." *Evolutionary Programming VII.* Springer Berlin Heidelberg, 1998.
[21] Deb, Kalyanmoy, et al. "A fast and elitist multiobjective genetic algorithm: NSGA-II." *IEEE Transactions on Evolutionary Computation,* 6.2 (2002): 182-197.
[22] Talaat, H.E. and Al-Ammar, E., "Optimal allocation and sizing of distributed generation in distribution networks using genetic algorithms", *in Electrical Power Quality and Utilisation (EPQU), 11th International Conference on, IEEE*. (2011), 1-6.
[23] Kouhi, S., Ranjbar, M.R., Mohammadian, M. and Khavaninzadeh, M., "Economic aspect of fuel cell power as distributed generation", *International Journal of Engineering* (1025-2495), Vol. 27, No. 1, (2014), 57-62.
[24]S. Chandramohan, N. Atturulu, R.P. Kumudini Devi, B. Venkatesh, "Operating cost minimization of a radial distribution system in a deregulated electricity market through reconfiguration using NSGA method," *Electr Power Energy Syst,* vol. 32, pp. 126–132, 2010.

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